VOLUME 3, NO. 4

ENVIRONMENTAL QUARTERLY

In This Issue . . .

Shock Testing Equipment and Procedures

♦

Designing *versus* Testing—the Design Engineer's Viewpoint

♦

Air Force Develops Environmental "Slide Rule"

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Vol. 3, No. 4 Fourth Quarter 1957

ENVIRONMENTAL QUARTERLY

Official Publication of the Environmental Equipment Institute and the Institute of Environmental Engineers

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The General Manager Speaks . . .

The Annual Technical Meeting of the IEE each April always gives rise to a surge of interest in the Society. Each year the meeting is followed by a number of new applications for membership. The encouraging part of this has always been that the number has increased every year. True to the pattern, 1957 has been the best year to date. For three months following April we have averaged better than 50 new members a month, and our total membership has now risen to above 350.

In comparison with older engineering societies, this is not an impressive total, and we are not going to brag about it. On the other hand, it is something which should give everyone connected with environmental testing a great deal of satisfaction. Only a few years ago environmental engineers were unknown. When the Science Section of the EEI was formed, scarcely anyone knew that such a branch of engineering existed.

Today that is changed. The rapid rise in membership shows how eagerly engineers in this phase of activity wanted a professional forum and their own professional identify.

How many members can we hope to have when we have reached maturity? No one knows, even approximately, but everyone is now sure that our goal of 500 for 1957-58 is modest, and entirely within the limits of possibility. The rate of membership growth has fallen off in August and September but this was to be expected. The effect of the April meeting had worn off and the summer vacation period was making itself felt.

We can confidently look forward to further increase as the fall programs of the local chapters get under way. Competition is keen among the chapters to become the leading chapter in the Institute. This is the part of the program of IEE which has heretofore been lacking. With five local chapters either chartered or ready to become so, and with several others in the formative stages, we are now a complete national professional society, and we can confidently expect to meet and better the goal of five hundred members by next April. Let's try.

GEORGE D. WILKINSON
General Manager, IEE and EEI

REAR ADMIRAL DUFE
TO SPEAK AT IE
ANNUAL MEETING IN 195

Rear Admiral George Dufek, Commander, U. S. Na Support Force, Antarctica, has accepted an invitation deliver a luncheon address next April 17 before the Seco Annual Meeting of the Institute of Environmental E gineers in New York City, according to a recent announ ment by Mr. Henry F. Sander, President of the Institu and Chief Test Engineer, Vapor Heating Corp.

In the event that Admiral Durek has not returned to t United States following the completion of Operation De Freeze III in Antarctica by early April, a pre-arrang substitute speaker will take his place, Mr. Sander said.

Partial Program

According to Mr. Arthur Billet, Program Chairman f the meeting, and Vice-President of the IEE for Local Cha ters, primary subjects for the two-day session are to b acoustic noise, vibration, radiation, climatic conditio and explosion. Mr. Billet is Staff Engineer at Vick Incorporated. Mr. Billet said that the following portio of the program have been firmly committed: "The Spa Satellite and Space Travel," Kurt A. Stehling, U. S. Na Research Laboratory; "Salt Spray Testing," W. B. Yarc WADC (Wright Air Development Center); "Enviro mental Equipment Used in the B-58 Development," Kuzmickey, Convair, Fort Worth; "Radiation Effects I formation Center," John R. Grimm, WADC; "Non-d structive Testing in the Atomic Energy Field," Gerold Tenney, Los Alamos, N. M.; "Combined Effect of M chanical and Radiation Stress," T. C. Helvey, The Mart Co., Orlando, Fla., "New Environments and Simulati Methods," W. A. Scholl, WADC; and three movies "Design for Environment" (Air Force), "Vibration Pr lems in the Design of Shipboard Electronic Equipmen (Navy), and "Environmental Factors Affecting Reliabil of Electronic Equipment" (Navy).

The complete program will be published in the Fi Quarter 1958 issue of the *Environmental Quarterly*, whi will be in the mail mid-January.

Committee on Arrangements

The overall Committee on Arrangements for the 19 meeting is chaired by Mr. Roger J. Amorosi, Executi Vice President of the IEE, and President of Parameter Inc. Other members of the Committee on Arrangemen are: Facilities and Finances, Mr. John Cammarata, He Environmental Test Sect., Arma Div., American Bos Arma Corp., and Publicity, Mr. Norman Meyers, Proje Engineer, Stratos Div., Fairchild Engine and Airpla Corp.

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SHOCK TESTING PROCEDURES

C. A. MILLS, Canadian Westinghouse Company Limited

Shock testing is now used for everything from jet and rocket take-offs . . . to naval near misses . . . to handling, transportation and rough landings of Signal Corps materiel. From our very good neighbor, *Canada*, comes this brief history of shock testing plus a description of current devices and techniques.

HISTORY

Shock test machines were among the first instruments used in an attempt to produce laboratory conditions that simulate those met in the field. The need to simulate near-misses by torpedoes, mines, etc., resulted in the development of the naval impact machines. At the time this need was recognized, accelerometers capable of measuring the conditions were not available and hence empirical design methods were used.

Investigators found that certain items of equipment survived the high shocks produced by near-misses. These items were then mounted on test machines and the force of the impacts increased until failure resulted. The test condition was then stated to be slightly less stringent than this point. This method of machine design made correlation of tests from laboratory to laboratory very difficult and the philosophy of specifying a particular machine was adopted. As instrumentation improved, attempts were made to define the test condition, but the variation from test machine to test machine precluded this possibility. The high, medium, and low impact machines are developments of this period.

During World War II the need for shock machines capable of simulating lower accelerations became apparent. These were to simulate conditions such as handling shocks, transportation shocks, rough landings, etc. In the interests of rapid design and manufacture, many varieties of test methods came into use — for example, dropping from windows and gantries onto sand, spring, rubber, etc. The U.S. military authorities later standardized their test conditions. This resulted in the "medium impact machine" named in specifications for testing both equipment and components. The spring type unit was also standardized for some components.

MR. MILLS is in charge of the Environmental and Appraisal Laboratory at Canadian Westinghouse. He holds the Higher National Certificate in electrical (telecommunications) engineering, The Polytechnic, Regent St., London, England, with endorsements in mechanical engineering, optics, acoustics, and mathematics. He has studied mechanical vibration at the Northampton Polytechnic, also in London. Mr. Mills is a member of the IEE, the Inst. of Electrical Engineers, Assoc. of Prof. Engrs. of Ontario, and the Canadian Industrial Management Assoc.

Since the specifications called for particular test machines and detailed test methods, the development of new types of test machines was discouraged. These machines had very wide tolerances on the deceleration produced for a given height and number of blocks in the case of the sand test machines. Thus the specifications gave approximate G figures and duration while stating definite test methods. With these empirical test conditions, the tendency on engineering was to work to large safety factors if a test waiver could not be arranged.

With the advent of high performance airborne machines, both manned and unmanned, the weight factors became more serious. This meant that the practice of beefing-up a piece of equipment to withstand shock had to be stopped to remove unnecessary materials. However, before safety factors could be reduced, two major questions had to be answered:

1. What is the actual airborne environment?

2. What are the test conditions produced in the laboratory?

Once these problems were faced, instrumentation made great strides, with the result that the actual conditions in piston aircraft became comparatively well known while those in the jets are still under consideration. When these conditions had been measured, steps were taken to develop test machines capable of simulating these conditions.

and EQUIPMENT

In the attempt to meet these defined test conditions, several new types of shock machines were developed, for example: lead block decelerators, hydraulic machines, and pneumatic machines.

Naturally, in the development of test machines to meet these conditions, several variants of each type resulted. However, these variants are less serious than formerly, provided that the shock wave form can be measured and is similar from machine to machine. Also a prime requisite of any test apparatus is that test conditions must be reproducible within reasonable tolerances.

Purpose of Shock Testing

An examination of these new requirements showed that shock machines could simulate:

Normal operating accelerations, such as, jet take-offs, landings, maneuvering.

Emergency landings where equipment must not come loose and injure personnel.

High acceleration bursts of vibration, that is, transient conditions produced by rough engine operation, maneuvers etc.

Definitive Test Conditions

A true definition of a shock wave can be given only by one of three records: Acceleration/time, velocity/time, or displacement/time.

This record is necessary in order to completely analyze the test requirements and compare these with the simulated test conditions. In all three cases it is also necessary to define the bandwidth of the measurement system.

Interpretation of Shock Waves

To interpret a shock wave fully these factors must be considered: Rise and decay times, duration of pulse at mean acceleration, mean acceleration, and peak acceleration.

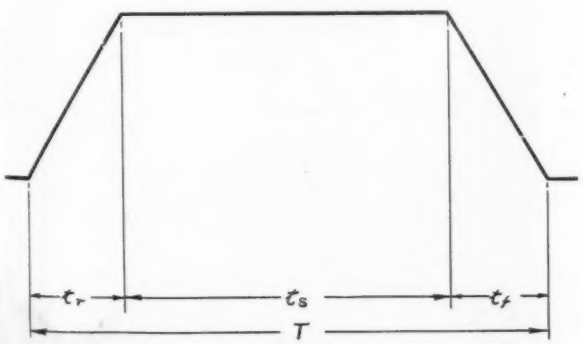


Figure 1. Reference shock waveform.

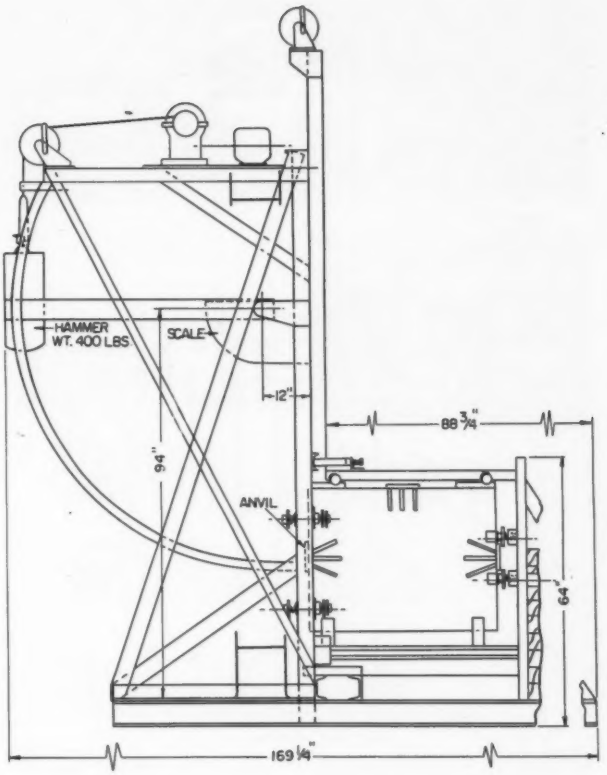


Figure 2. Lightweight impact shock test machine.

In the case of an idealized shock wave (Fig. 1), the acceleration is applied infinitely fast and maintained as a flat-topped pulse for a given duration and then removed infinitely fast. In this condition $t_r = t_f = 0$. If this pulse is then analyzed it will be found that frequencies are present between the limits of infinity and $\lambda/4 = t_s$. If this wave were applied to a mechanical structure, all resonances would be excited within these limits and these vibrations would last for a period longer than T, this period being dependent on the damping in the system. There would also occur a unidirection deflection resulting from the acceleration. This deflection would initially be that produced by twice the acceleration and it would then return to a deflection produced by the acceleration proper providing the acceleration is still being maintained. This apparent amplification is present as the acceleration is instantaneously applied.

In practice, however, these ideal conditions are not encountered and the state where t_r and t_f are both finite periods may be considered. In this case analysis will show that the whole spectrum from $\lambda/4 = t_s$ to infinity is not excited but only a limited band of frequencies. The

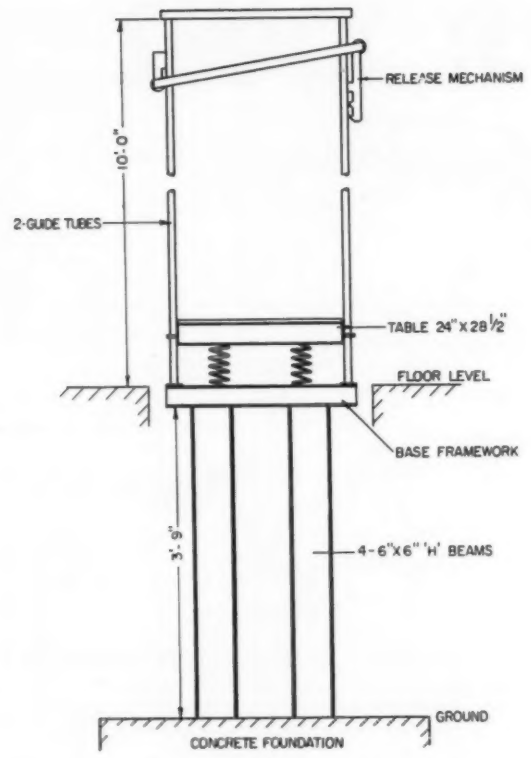


Figure 3. Spring type drop tester.

greater portion of the energy available will be expended in exciting resonances in the band between $\lambda/4 = t_r$ and $\lambda/4 = t_s$. Since t_r is now a finite value, the apparent amplification of 2 will not be present. However, the factor "infinitely fast" is a relative term between t_r and t_0 where t_0 is the period of the resonant frequency under consideration. If $t_0 \gg t_r$, then the acceleration is applied infinitely fast and the amplification becomes 2.

If this ratio is varied, the following table results:

t_r/t_0	Amplification
0	2
0.2	2
1	1.8
2	1.2
3	1.1

If one reaches the condition where $t_r \gg t_0$, then shock tests and sustained acceleration tests become synonymous. A centrifuge can then be used to produce the uni-directional movement produced by a shock test in the case of a system with only one major resonance. In practice, systems normally have more than one major resonance and also the test engineer is interested in examining the effects of the transient vibrations produced on various parts of the system in addition to the uni-directional movement. Thus the sustained accelerator or centrifuge cannot be used in lieu of shock test equipment but rath the two tests are complimentary.

Shock tests can also be used to simulate high accele tion transient vibration conditions, provided that th shock test method is one where the rise time and dur tion are controllable. Many transient conditions are suc that vibration testing equipment cannot effectively simu late conditions and hence this application becomes im portant.

The rise time t_r on a histrogram is effected by the ban width of the instrumentation used and care must b taken to ensure that the definition of the test conditio is not effected by this factor. This implies that the ban width of the instrumentation system must be wid enough to pass all frequencies present.

Specifying the Test

The chief requirements of the specified waveform are Repeatability; use of a waveshape that can be analyze so that test results can be compared with actual cond tions; and accelerations that are compatible with tho met in practice.

These factors can be achieved by using a wavefor that approximates an ideal shock, that is, a trapezoid wave with a finite time of rise and a relatively consta acceleration during the pulse. In practice, a pulse wi a rise time of approximately 500 microseconds and duration of 8 to 10 milliseconds will excite all fr quencies in the band of 25 to 500 cps. In most structure this will cover all serious resonances.

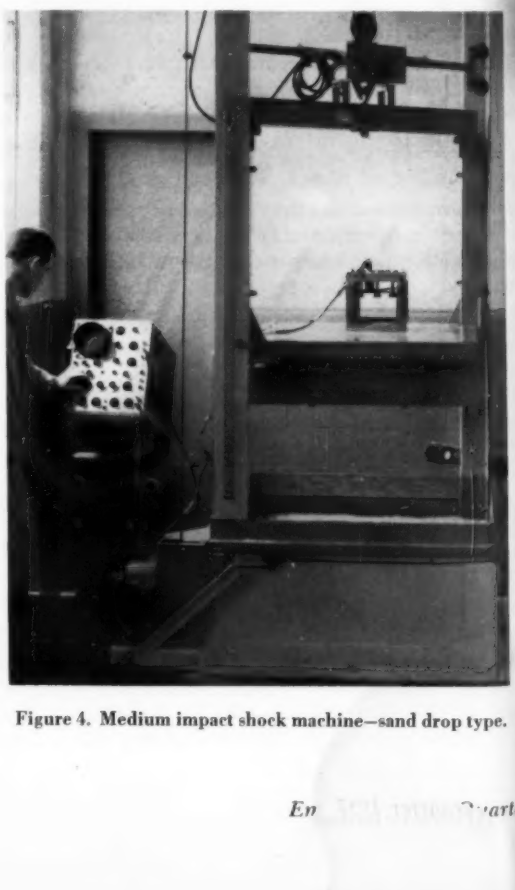


Figure 4. Medium impact shock machine—sand drop type.

Measurement Techniques

Virtually all types of acceleration, velocity, and displacement transducers have been used at one time or another to determine the shape of the shock wave present either in practice or in laboratory simulation.

Three main methods are in use in the general field at the moment with other methods being developed in the various research laboratories. These methods are characterized by the type of instruments used: crystal accelerometers, strain gages, and indent accelerometers.

The first two methods are in many cases complimentary owing to the frequency spectrum covered by the two instruments. The crystal accelerometer with its very high resonance (10 to 30 Kc/s) will follow the most rapid rise in acceleration liable to be encountered in general practice. This instrument, however, will not follow a sustained acceleration even for a few milliseconds since the electrical signal generated is dependent on changes in crystal compression produced by the effects of acceleration on the accelerometer lead. Thus the output signal falls exponentially during any maintained acceleration. On the other hand, the strain gage accelerometer relies on mechanical strain to produce an unbalance in the bridge circuit normally used and hence sustained accelerations can be measured from milliseconds upwards. These instruments have the disadvantage of having a resonant frequency usually less than 800 cps with the result that very fast times of rise can not be followed.

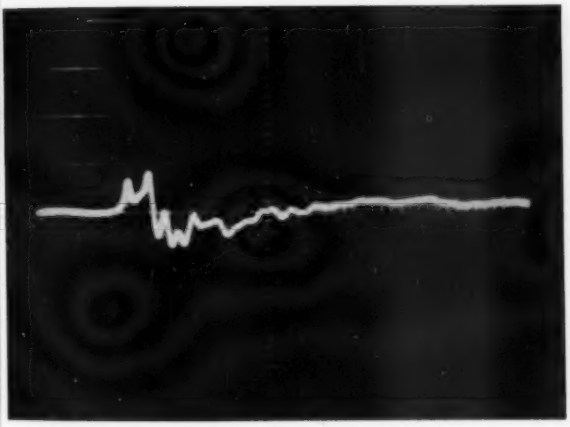
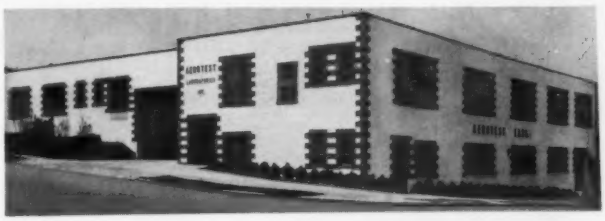


Figure 5. Typical waveform on medium impact shock machine.

In practice, however, the test engineer is quite often interested only in frequencies up to 500 cps, and under these conditions either instrument will give satisfactory results. Experiments have shown, though, that for accuracy the complete measuring system should be calibrated as an entity rather than by its separate components. If an upper limit of 500 cps is required, then the filter limiting this in the measurement system should be included in the calibration.

(Continued on Page 19)



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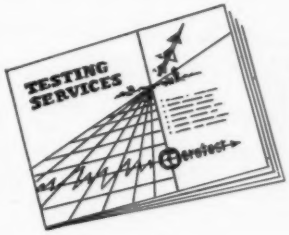

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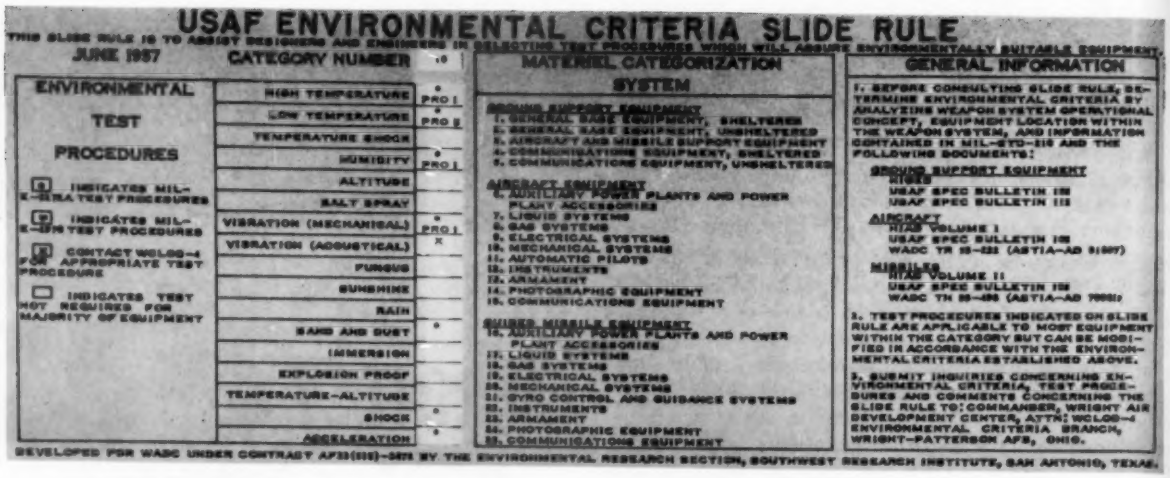

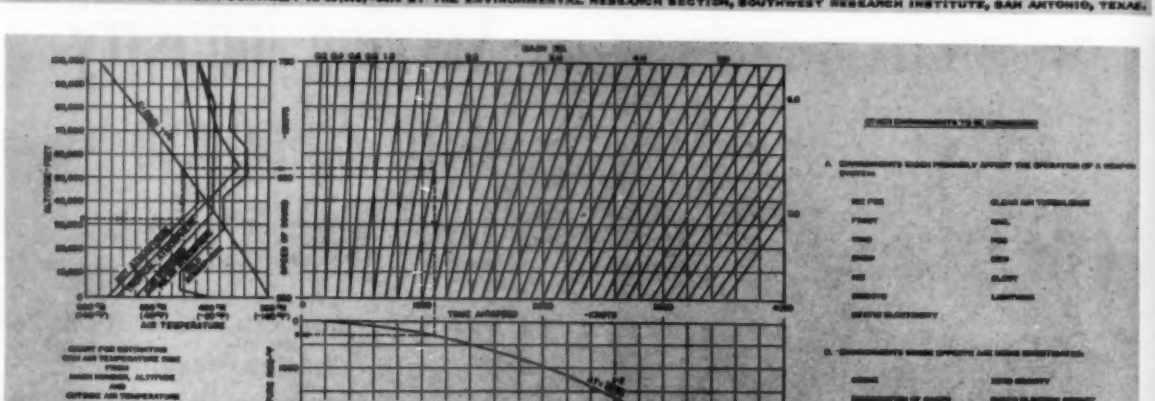

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		A	B	C	D	E	F	G	H	A	B	C	D
TEMPERATURE	MAX POWER	71°C 1 HOUR	95°C 10 MINUTES	125°C 10 MINUTES	135°C 10 MINUTES	260°C 10 MINUTES	275°C 10 MINUTES	400°C 10 MINUTES	500°C 10 MINUTES	-54°C	-54°C	-54°C	-54°C
	MIL POWER	54°C 4 HOURS	71°C 1 HOUR	95°C 1 HOUR	135°C 1 HOUR	260°C 1 HOUR	275°C 1 HOUR	370°C 1 HOUR	500°C 1 HOUR	TO	TO	TO	TO
	CRUISE POWER		54°C 4 HOURS	71°C 4 HOURS	95°C 4 HOURS	135°C 4 HOURS	150°C 4 HOURS	260°C 4 HOURS	370°C 4 HOURS	95°C	371°C	538°C	1093°C
TEMPERATURE SHOCK		-54 TO 71°C 20 MINUTES	-54 TO 95°C 10 MINUTES	-54 TO 125°C 10 MINUTES	-54 TO 135°C 10 MINUTES	-54 TO 260°C 10 MINUTES	-54 TO 275°C 5 MINUTES	-54 TO 400°C 5 MINUTES	-54 TO 500°C 5 MINUTES	-54 TO 95°C 10 MINUTES	-54 TO 371°C 5 MINUTES	-54 TO 538°C 5 MINUTES	-54 TO 1093°C 5 MINUTES
ALTITUDE		35,000'	55,000'	60,000'	70,000'	80,000'	90,000'	150,000'	150,000'	100,000'	3,000,000'	3,000,000'	3,000,000'
ALTITUDE SHOCK		0-35,000' 30 MINUTES	0-55,000' 10 MINUTES	0-55,000' 10 MINUTES	0-70,000' 5 MINUTES	0-85,000' 5 MINUTES	0-90,000' 5 MINUTES	0-150,000' 5 MINUTES	0-150,000' 5 MINUTES	0-55,000' 10 SECONDS	0-3,000,000' 30 MINUTES	0-3,000,000' 30 MINUTES	0-3,000,000' 30 MINUTES
SHOCK										20 G 11 MS	20 G 11 MS	20 G 11 MS	20 G 11 MS
MECHANICAL VIBRATION		10-55 CPS .06 DA	5-55 CPS .06 DA 55-500 CPS 10 G	5 - 55 CPS .06 DA		55 - 2,000 TO 2,000 CPS 10 G TO 20 G				5-55 CPS 55-2000 CPS	5-55 CPS 55-2000 CPS	POSSIBLE COMPLEX WAVE SIMULATION	?
ACOUSTICAL VIBRATION	EXTERNAL	150 DB	154 DB	145-161 DB	148-169 DB	152-173 DB	155-175 DB	155-180 DB	155-180 DB	150-175 DB	150-175 DB	150-175 DB	150-175 DB
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Air Force Environmental Critical Slide Rule. From top to bottom: Front and back of outer sheath; front and back of sliding element. Only the upper third of the front of the slider is visible above the diagonal line.

Environmental Criteria SLIDE RULE

R. K. HANKEY, Environmental Criteria Branch, Wright Air Development Center

Air Force Tool Available to Its Contractors

To assist designers and engineers in selecting test procedures that will lead to environmentally suitable equipment, the U. S. Air Force has developed a form of card board "slide rule." Front and rear faces of both the outer sheath and the sliding strip are shown on the opposite page. The assembled tool appears in the photograph at right.

The Air Force does not consider this slide rule the last word, and invites comments of any kind, so that through refinement and revision the rule can become a more and more important tool in the environmental field.

Under an Air Force study contract, the Southwest Research Institute, San Antonio, Texas, developed the slide rule during a three-phase program: arranging materiel into categories, analyzing available criteria, and synthesizing the first two phases for presentation in the slide rule format. Mr. William Scholl, of the Environmental Criteria Branch, WADC, first conceived the idea of the condensed slide rule technique.

So complex is the environmental field that it is not possible to outline a set of test procedures for a category of equipments or even a particular equipment without a study of the operational concept of the weapon system involved, location within the system, protection provided, etc. Even so, the slide rule should prove invaluable as a source of both criteria and procedure references, and as a guide to the most applicable testing procedures.

The three major categories appearing on the rule are ground support, aircraft, and guided missile equipment. In the selection of sub-categories, the contractor considered equipments likely to be used in the same environment, the methods by which equipments are actuated, or a combination of these two into a system such as communications. For ground support equipment, shelter was an important factor.

(Continued on Page 10)

MR. JOHN R. GRIMM, Asst. Chief, Environmental Criteria Br., WADC, since 1952, has been appointed to a position in the Programs Branch of the WADC Staff. Mr. Grimm has represented the Air Force in the affairs of the EEI and the IEE since 1953, and has been an active member of the Committee for the Handbook of the Environment. Mr. R. K. Hankey, author of the above article, has been designated as Mr. Grimm's successor.

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DIRECTORY OF NEW IEE MEMBERSHIPS

A list of those who have joined since the last issue of the Environmental Quarterly. Where home addresses are shown, company affiliations appear in parentheses.

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ENVIRONMENTAL CRITERIA SLIDE RULE

(Continued from Page 9)

The slide rule also provides environmental criteria references for ground support, aircraft, and missile equipment, and a simplified chart for determining ram air temperature rise. An instruction sheet is included with each rule.

For additional information about this slide rule or about Air Force environmental criteria, contact Commander, WADC, attention Environmental Criteria Branch, WCLOD-2, Wright-Patterson AF Base, Ohio.

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ENGINEERING DEVELOPMENT —BY CALCULATION OR TEST?

RICHARD RAVENHALL, JAMES E. FEE and
GEORGE W. BISHOP, Bishop Engineering Company

Environmental engineers are as interested as the authors in the question posed here: "Where should analysis stop and testing begin?" Freely admitting the need for testing, these design engineers say, "Design something that can be calculated." They seek the right balance between design man-hours and test man-hours.

When the development of a mechanical device is undertaken by engineers a rational allocation between calculation man-hours and testing man-hours must be established. A vital question facing development engineers today is: Where should analysis stop and testing begin? It is the purpose of this article to present the considered opinions of several mechanical design engineers on this subject.

The ideas expressed here have to do primarily with the development of *mechanical* devices in relation to environmental testing, in particular as illustrated by gravity loading and vibration tests.

Two Methods

It is our conviction that mechanical engineers use development procedures that lie between these extremes:

1. "Build it and test it."
2. "Design something that can be calculated."

We believe that the second approach is much more economical with respect to both time and money. Also, Procedure 2 has been sadly neglected in the past in favor of Procedure 1.

Probably the "Build it and test it" predominance of development engineering has evolved from an influx of test engineers into design and development engineering fields; to them this approach is rational and straightforward. Also, the "Build it and test it" procedure may appear as the only way out of a tight spot to the engineer with little analytical experience.

To appreciate Procedure 2 it is mandatory that engineers be acquainted with some of the successful solutions that have been obtained purely by calculation. When sufficient confidence has been built up in calculation methods, it is possible for engineers to appreciate the wisdom of designing something that can be calculated readily. Furthermore, we believe such engineers will insist upon Procedure 2 and will vehemently reject Procedure 1.

Almost every day we hear engineers say, "But this doesn't work according to the theory — and therefore analysis is useless." Our answer is that the engineer must be thinking of the wrong theory. *We have yet to see Newton's laws disproved in the field of mechanical devices.*

The Choice Dictated by Economy

We have indicated that the test procedure should be the final exam and graduation exercise while the analysis should be the backbone of the development process. This choice is furthermore dictated by economy. We don't believe that testing a piece of mechanical equipment can produce as valuable results as can be obtained from a reasonable amount of analysis when compared on the basis of cost. We qualify this statement by the term "reasonable amount of analysis" and we agree that both analysis and test are necessary, but the proper amount of each is what we wish to discuss in this article.

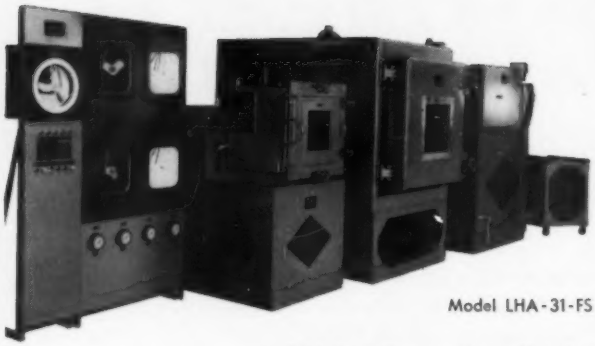
First of all, too many organizations overlook sufficient analysis and proceed to develop items by a costly test and revise program. Possibly the U. S. Government's practice of testing development prototypes before final acceptance gives rise to a test and revision development program on the part of the contractor as a logical method of completing the project. Whatever the reason, this expensive process is usually not justified.

We believe that some testing can be valuable during the design phase of a development project if it is applied to separate components or isolated items. Such testing would be conducted to confirm the calculations or to indicate the percent error in the calculations. It should be appreciated now that such testing would be a minimum when the item has been designed so that it can be calculated. The percent error will be exceedingly small if simple shapes properly oriented have been selected for the design.

Sometimes the available data on a new material may not include all of the desired characteristics, and in such case again a test is invaluable. But it is a test of a component and not of an entire piece of equipment.

When a prototype machine has been developed according to the above method, a final test may indicate the

(Continued on Page 21)



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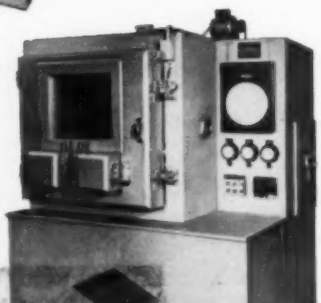
Supplied in sizes from 2 to 100 cu. ft. net working space, these chambers operate to —100° F at rapid reduction rate and provide controlled humidity through a range of 35 to 175° F at 20 to 95% r.h. Full controls available.



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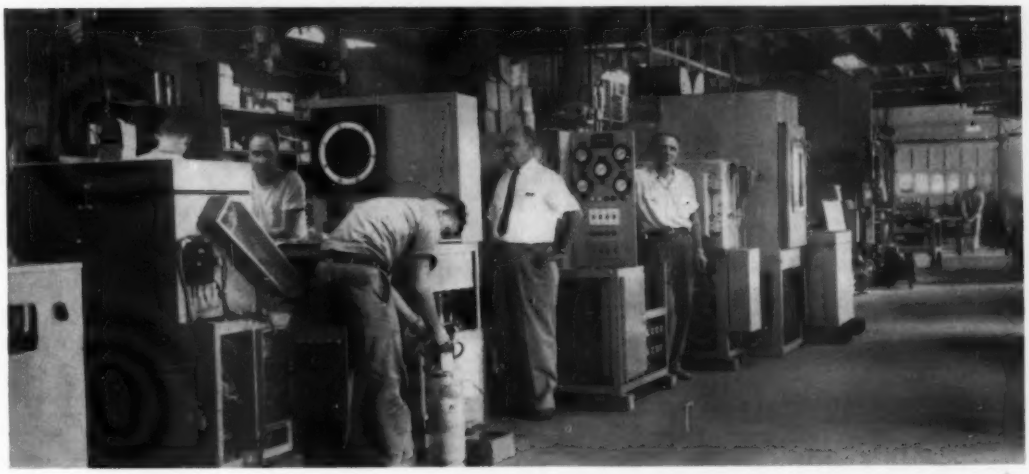


The advent of World War II gave tremendous impetus to the requirement for environmental testing equipment, and the founders of Standard Cabinet Company, with many years of experience in the application and design of commercial and industrial mechanical refrigeration systems, recognized the potential future of an infant industry.

Early in 1942 they were called upon to design, build, and install environmental simulation equipment considered in those days to be extreme. This equipment was engineered and constructed so that it is still in operation at a major Government testing facility.

During the ensuing years, Standard Cabinet Company has endeavored to keep abreast of the ever-changing and increasingly difficult requirements. Their experience through the years of successfully manufacturing equipment for numerous applications designed to simulate temperature, humidity, and altitude has proved invaluable in the manufacturing plants of industry, in the research and development laboratories, and in agencies of the Government.

The present plant location in Carlstadt, near the New Jersey exit of the Lincoln Tunnel to New York City, was selected in 1942 for its central location, availability, and service facilitation.

The uninterrupted history of Standard Cabinet Company through years, including the readjustment period at the close of World II, when environmental chambers were a surplus commodity, t to the distinction of being the oldest company in this an[illegible] same ownership and management. This has resulted in continuous and progressive product improvement in design, performance, and reliability.

The present plant of Standard Cabinet Company is modern and well equipped to design, fabricate, and construct cabinets, chambers, and walk-in facilities. Its product quality is evidenced by the repeated patronage of its many customers through the years, and the recommendations by these patrons to numerous new users of environmental equipment.

During its fifteen years of uninterrupted history, and with accent on product improvement, the Standard Cabinet Company has successfully developed and designed extremely difficult environmental applications, as well as established a line of standard chambers. They have a research and development laboratory at their plant in Carlstadt, New Jersey, equipped for all environmental simulation requirements under MIL-E-5272A, and related specifications, and can thus observe the performance of their equipment under actual operating conditions. This operation has given the Standard Cabinet Company a unique opportunity to observe the difficulties experienced in the field and thus improve product design and reliability from the user's point of view.

The Standard Cabinet Company manufactures a complete line of chambers in a wide range of sizes, including temperature, humidity, altitude, explosion, fungus, salt spray, sand and dust, rain, and sunlight.

In keeping with the tradition established in 1942, substantial design and rugged dependability is always the first consideration.

Instrumented to Create Programmed Sequence of Climatic, Speed, and Altitude Environments Automatically.

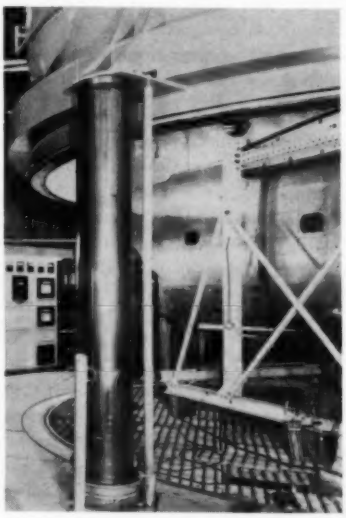
$1 MILLION TEST CHAMBER Simulates Extreme Flight Conditions

FRANK P. HOUPT, Instruments Div., Fischer & Porter Co.

Effects on aircraft of conditions during take-off, stratosphere cruising, and landing can now be observed by Douglas engineers in what is believed to be the only $1,000,000 environmental test chamber in the United States. It is installed at Douglas Aircraft Company, Inc., Tulsa, Oklahoma. The new chamber will accommodate fuselage and wing sections as large as 12 by 18 by 12 feet.

The chamber consists of two dome-shaped steel sections 24 feet in diameter. The 70,000-pound top section is 18 feet high and can be lifted 12 feet above floor level by three 18-inch diameter hydraulic jacks. The bottom section extends 15 feet below floor level and houses both test equipment and instruments. There are 120 temperature pick-up points, 8 pressure pick-up points, sensing elements for chamber temperature and pressure, cooling coils, blowers, and all basic piping feeding into and out of chamber.

Heart and brain of the complex system is the Fischer & Porter instrumentation, which accounted for 15 percent of total cost. The six pneumatic program-controlling instruments are so designed that for any given combination of climate, speed, and altitude, it is necessary only to *cut a cam* and put it in the program transmitter to obtain automatic control of the desired cycle. All instrumentation required for operation is in a 30-foot central control con-



sole, a portion of which appears at left in the photographs.

Engineers have a high degree of control and flexibility, both for operating the present test system on existing aircraft and for possible future aircraft component testing. The bleed air, ram air, or altitude systems may be controlled either manually, automatically under steady-state conditions, or automatically under program-control conditions.

Three basic systems lead into the bottom section: the system that simulates air bled off the compressor of a jet engine, the ram air system that simulates the air scooped from the atmosphere, and the vacuum system that simulates altitude. These operating variables are recorded and controlled:

Bleed air system—temperature from ambient to +1000 F, pressure from 0 to 250 psia.

Ram air system—temperature from –100 F to +250 F, pressure from 0 to 30 psia.

Vacuum system—temperature from –100 F to +250 F, altitude from 0 to 120,000 ft.

Two other bleed air systems are available for production testing and development testing. Temperature control range in each is from ambient to 800 F, and pressure is from 0 to 250 psia. For development testing, flow signals are indicated to an accuracy of ½ of 1 percent of instantaneous flow rate. System pressures are observed on Press-I-Cell indicating instruments having 200-inch-long film scales with an accuracy of one part in 2000.

Evacuation is done by two reciprocating 6500-cu.-ft.-per-

(Continued on Page 27)

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NEW PRODUCTS

News of product developments are welcomed by the editor. Send releases to the *Environmental Quarterly*, 9 Spring Street, Princeton, N. J.

For more information, circle the key number on the Reader Service Card.

1—Viewing glass units for environmental test chambers. Up to ten "lights" of glass thick. Tolerates differences from –100° F to +350° F. Thermoseal Glass Corp., Camden, N. J.

2—New temperature test chamber, series 10, 10-cu ft work space. Low-cost chamber has single-stage and cascade refrigeration systems with hermetic compressors and air-cooled condenser. Compact. Requires single plug-in electrical connections. Four standard assemblies with temperature ranges of –40° F, –85° F, –100° F and –120° F, and +240° F and +350° F. Tenney Engineering, Inc., Union, N. J.

3—Model 932 pressure switch for explosive atmosphere. Responds to differential between two variable pressures or a variable and a reference pressure. Four classes of proof pressures from 500 to 12,000 psi. Makes or breaks a circuit on varying pressures at any point within the adjustable range of the model selected. Operates in any position. Barksdale Valves, Los Angeles, Calif.

4—Equibar, a unique gas-pressure transducer for high-speed measurement of pressures from 10^{-6} to 15 psi. Trans-Sonics, Inc., Burlington, Mass., claims Equibar useful as airborne transducer and as a laboratory tool for pressure studies and absolute vacuum pressure measurements down to 10^{-6} psi.

5—Model S-8 transducer, variable-reluctance, dual-coil, diaphragm-type, for absolute, differential, or gage pressure. Designed for rocket engine test stand studies, blast wave measurements, etc. Ultra-dyne Engineering Labs., Inc., Albuquerque, N. M.

6—WEATHER-LABS modified to include feed-through terminal blocks (all sizes) for testing electrical devices under various temperature and humidity conditions when connected to external instrumentation. Removable center mullion so that large units can be tested. Hudson Bay Co., Div. of Labline, Inc., Chicago.

7—Calorel aluminized conductor wire has high resistance to heat up to 1500° F and no embrittlement temp. Same conductivity and temperature coefficient as nickel wires, according to Continental Wire Sales Co., Wallingford, Conn. Resistance is about 6 times that of copper. Increases 4 times in 1000° F.

8—SLM differential pressure indicator (Model DPI-114) measures both fast and slow transient differential pressures at any two points in pneumatic or hydraulic system, or on an aerodynamic model. Measures a 0.1 psi change at 3000 psi level. 0 to 50,000 cps. Continuous operation at 600° F. Can be converted to precision vibration indicator. Kistler Instrument Corp., N. Tonawanda, N. Y.

9—Pressure pick-up, variable resistance-type, adds less than 0.004 cu in. to volume of system under test. For use with liquids and gases. Excellent temperature stability from –65° F to +250° F. Standard Controls, Inc., Seattle, Washington.

10—Chilling machine, Model 10L-2, used to achieve complete stability and maximum hardness in processing of metal parts. Six to 45 cubic-foot sizes with configurations for sheets, bars, or odd shaped parts. Harris Refrigeration Company, Cambridge, Mass.

"Design for Environment"

New Air Force Film Depicts Environmental Effects from Present to Era of Earth Satellite

To orient technical personnel in the vital role of environmental engineering in the development of weapon systems, the Air Force has produced a new color film, "Design for Environment."

Film SFP 385 projects the imagination from present-day weapon-system environments to those of the satellite. It animates known environmental effects and suggests unknown effects, and it outlines the present USAF Environmental Program. The role of the Air Force project officer or engineer in the solution of environmental problems in hardware development is also presented.

Technical advisor was Mr. E. C. Theiss, Chief, Environmental Criteria Branch, Wright Air Development Center, and scriptwriter was Mr. Robert G. White, Air Photographic and Charting Service. Industry scenes were shot at North American Aviation, Lockheed Aircraft, and Northrop Aircraft. X-ray footage was furnished by Rototest Laboratories, and landing-gear drop scenes by Lockheed; Kling Film Productions, Inc., produced the movie.

The 16-mm sound film is unclassified and running time is 33 minutes. Requests for prints should refer to SFP-385 "Design for Environment," and should be forwarded to Civilian in Charge at one of these:

Western Film Exchange
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Eastern Film Exchange
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Marietta, Pennsylvania

Southern Film Exchange
Orlando Air Force Base
Florida

Midwestern Film Exchange
San Antonio Air Force Station
2100 N. New Braunfels Avenue
San Antonio 8, Texas

RADIATION EFFECTS INFORMATION CENTER

The Air Force has established the Radiation Effects Information Center at the Battelle Memorial Institute, Columbus, O., to make the latest radiation effects data available to the AF 125A Weapons System program, and to Army, Navy, AEC, and other government agencies within the staff limits of the REIC. The next issue of the *Environmental Quarterly* will carry a report on REIC by Mr. John R. Grimm, AF Task Engineer for the REIC.

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IEE LOCAL CHAPTER NEWS

Chicago is second chapter to be chartered

CHICAGO—At a formal meeting August 26, the Executive Committee of the IEE voted unanimously to accept the application of the proposed Greater Chicago Area Chapter for status as the second fully accredited local chapter.

Mr. Steve Danko, of Motorola, attended the Executive Committee meeting as National Director representing the Chicago Chapter, but did not sit in until the Committee had considered and accepted the application of the new chapter and was formally invited to participate.

At an earlier meeting, August 7, the proposed Chicago Chapter had met and elected the following officers, and these men now constitute the governing body of the new chapter:

President — Mr. John R. Boyle, Boyle Engineering Laboratories.
Vice President — Mr. Edward A. Feldman, J. P. Seeburg, Incorporated.
National Director — Mr. Danko.
Secretary — Mr. Don A. Brosseau, Roth Manufacturing Corporation.
Treasurer — Mr. Robert H. Jacobson, The Armour Research Foundation.

Following the August 7 meeting, the new Executive Committee of the Chicago group held its first executive session. As an outgrowth of this meeting, a request was made to Mr. H. F. Sander, IEE President, for the IEE to hold its 1959 meeting in Chicago. The Chapter Executive Committee also set wheels in motion to map a program of Chapter meetings for the 1957-58 meeting season.

BOSTON — The proposed Boston Area Chapter, under the guidance of Temporary Chairman Robert J. Graeff, Equipment Sales Co., Inc., held its first general meeting on August 13. Over 100 persons attended this meeting to make it the largest of its kind ever held. Speaker of the evening was Mr. Galt Booth, Chief Development Engineer of the MB Manufacturing Company. His topic: "The Future of Random Motion Testing." The gathering was greeted and welcomed on behalf of the national society by the IEE Vice President for Fiscal Affairs, Mr. Harold C. Jones of Westinghouse Air Arm Division.

Mr. Booth approached his topic with a review of some of the purposes and objectives of random motion testing, developed a tabulation of existing specifications and trends, and by applying several assumptions about future performance requirements of interceptor missiles, arrived at an approximation of what vibration testing specifications may look like five to ten years hence. By comparing these random motion specs with equivalent sine-wave tests, he developed convincing arguments favoring the random type test as more economical and practical.

The Boston group expects to submit its proposed by-laws and make formal application for a chapter charter by the time this issue of the *Environmental Quarterly* is distributed.

Besides Mr. Graeff, the Boston Steering Committee includes: Mr. S. E. Abbott, and Mr. G. A. Jenson, AVCO Manufacturing Co.; Mr. A. L. Jorgensen, Raytheon; Mr. R. T. Lowe, Barry Controls; Mr. R. F. Martini, Massachusetts Institute of Technology, and Mr. M. T. Tolf, Acton Testing Labs.

The Membership Committee includes: Mr. E. Geolette, Massachussetts Institute of Technology; Mr. L. U. Hurley, AVCO Manufacturing Co.; Mr. E. M. Kenuon, Quartermaster Research and Development; Mr. R. J. Schreiber, Raytheon; Mr. Jack Shamroth, American Research Corp.; Mr. L. Stafford, Raytheon; and Mr. Tolf.

DETROIT — Just as this issue was going to press, the application for local chapter charter arrived at I E E headquarters. Detroit is the third local group to make such application.

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SHOCK TESTING

(Continued from Page 7)

With extremely high accelerations (over 1000 G), normal accelerometer reliability tends to fall off owing to normally minor faults being magnified. On tests of this nature, the test engineer is normally interested only in the peak G present. This can readily be measured by using the indent accelerometer. This instrument uses the penetration of a steel ball into a piece of material as the indication of the force exerted. This indentation can be easily calibrated by use of compression machines and normal hardness testers. This type of instrument has repeatable accuracy within the limits of Brinell Hardness tolerances.

Mounting Jigs

Great care must be taken in the design of mounting jigs to ensure that the resonant frequencies excited in these do not color the results of the test. Since the whole spectrum is excited simultaneously the interaction of the various resonances must be carefully examined. Ideally no resonant frequency should be present in the jig over the frequency band to be excited during the test. In this consideration, the effects of the test sample on the jig should not be neglected. In practice one of the great boons to jig design is that weight is not usually a problem (as in vibration testing where the power available may be limited) and hence jigs can be very sturdily constructed. The effect of the mounting table resonances will normally have been borne in mind during the design of this part of the machine.

Figure 6. Small lead block decelerator — used for calibrating transducers.

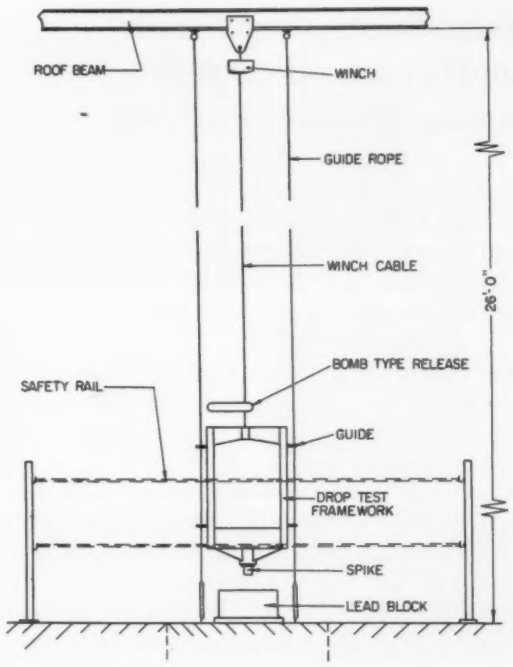


Figure 7. Large lead block decelerator.

TYPES OF TEST MACHINES

High Impact Machine

The lightweight impact machine is shown in Figure 2. The heavier units operate on a similar principle. The test sample is mounted on a metal mounting plate and the hammer raised to the height called for in the specification. On release the hammer swings down and strikes the table a blow. This blow can usually be applied normal to the plate or upward through the plate. Since both the hammer and the mounting table are of steel, the impact has a very high acceleration but a very short duration. The accelerations are frequently up to levels of several hundred G but with a duration of only a millisecond or so. The impact normally produces a very high acceleration vibration, the damping of which is largely brought about by the sample mounted on the machine. The vibration frequency produced is usually fairly high on these types of machines and hence the loading effects produced on the test sample are virtually those due to repetitive ideal shocks. As a result of this factor, the lightweight impact machine cannot be used to simulate a known-acceleration-versus-time histrogram.

(Continued on Page 23)

ENVIRONMENTAL EQUIPMENT INDUSTRY RECOGNIZED BY FEDERAL TRADE COMMISSION

The manufacturers of environmental test equipment have been formally acknowledged to comprise a new industry by action of the Federal Trade Commission in promulgating trade practice rules for this field under the Commission's trade practice conference procedure.

This step by the FTC represents the culmination of an active project of the Environmental Equipment Institute begun in 1953 shortly after the Institute was incorporated.

A statement by the Commission appearing in the introduction to these new rules is quoted as follows: "The rules are directed to the prevention and elimination of various unfair trade practices deemed to be violative of laws administered by the Commission. They are to be applied to such end and to the exclusion of any acts or practices which suppress competition or otherwise restrain trade.

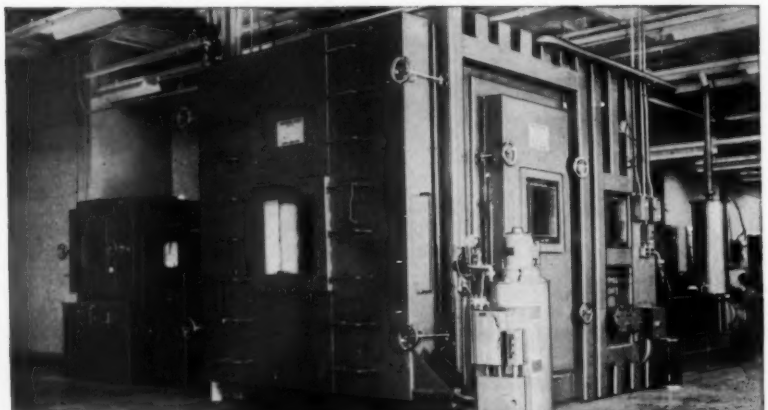
Preparatory to a report to the Commissioners that le to the final publication of the new rules this summe Mr. William Dixon, FTC attorney, conducted an indu try-wide conference in October, 1956, and a public hearin in April, 1957.

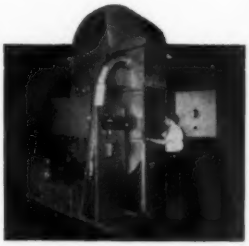
The FTC does not initiate action in cases of alleg violation of its laws or of any actions in restraint of trad but must wait until it receives a complaint in writing.

Members of the Federal Trade Commission are: Cha man, John W. Gwynne, Robert T. Secrest, Sigurd Ande son, William C. Kern, and Edward T. Tait. For copies the new rules, write Robert M. Parrish, Secretary, FT Washington, D. C.

Correction: Vol. II, Proceedings, Sec. Annual EEI Science Sect. Me ing, pages 69-70. Statement attributed to Mr. A. I. Dranetz shou read:

"There is in existence with a large east coast electronic manufactur a defense department contract to develop such a manual. If you wa to know who it is, I can probably find out for you."





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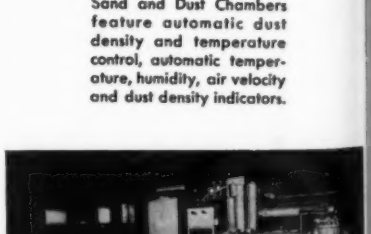

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ENGINEERING DEVELOPMENT

(Continued from Page 11)

need for revisions. Such indications will be qualitative, and the engineer will know how much change is required in a particular member and why, since he will previously have calculated the characteristics of the member and will know what was critical in it.

This is the economical approach to development engineering. The examples below have been encountered personally and have been largely responsible for our philosophy on this subject.

Examples

An aircraft bomb ejector had been designed by a group of engineers who relied on the "Build it and test it" technique. Prior to fabrication the design was reviewed by an engineer who showed by calculations that the ejector linkage joints would not operate as desired since friction would lock several of the joints, thus preventing motion. The group of engineers was unimpressed with this paper work and stated that the only way to be sure was to "Build it and test it." Fortunately, before fabrication, design revisions were made as suggested, reanalyzed, and then finalized in accordance with the calculations. This final design was simpler and, needless to say, easier to calculate. After fabrication, the vibration and gravity loading tests were successfully passed, thus confirming the validity of the analysis. Further testing indicated that this ejector mechanism would operate with even a slight increase in its coefficient of friction. But it was also proved that the original design would have required completely frictionless joints to perform as per specification or that it might only have been able to operate with less than 1% of the required loads applied. This would then have been completely rejected.

A chemical container was being designed and developed on a sub-contract basis. The customer's engineers were not convinced by the sub-contractor's analysis, which indicated that some of the vibration and gravity loading test specifications were not compatible and should be changed before fabricating the first lot of containers. The subcontractor's design met all of the test requirements after fabrication but far exceeded the one specification which was not compatible with the others. When the customer's engineers saw the calculations proved by the tests they insisted that the specifications be changed as originally requested. This inability to accept calculations for what they are worth thus resulted in excessive development costs and longer development time since this phase had to be performed over again.

(Continued on Page 22)

New Literature

News of literature of interest in the environment field is welcomed by the editor. Send releases to the *Environmental Quarterly*, 9 Spring Street, Princeton, N. J.

For copies of numbered publications, circle appropriate numbers on Reader Service Card.

1—New environmental test lab available to industry and government agencies. Electronic and electro-mechanical products and systems. Technical Bulletin 58-116, BJ Electronics, Borg-Warner Corp., Santa Anna, Calif.

2—Meter for measuring fluid flow under difficult conditions and at high temperatures and pressures. Hydraulic pressure of measured fluid "floats" turbine-type rotor. Rotor spins freely without slippage. Bulletin S-1. Potter Aeronautical Corp., Union, N. J.

3—Catalog of environmental test chambers and other test equipment. International Radiant Corp., New Cassell, L. I., N. Y.

4—Humidity-proof potentiometer. Model 228 carbon "Trimpot." Operating temperature range −55 to +95 C; 0.2 watt power rating at 50 C. Sealed against humidity, salt spray. Bulletin EN228/F/7. Bourns Laboratories, Inc., Riverside, Calif.

5—Small-case instruments, temperature and pressure. Low-cost. Corrosion-proof, weather-proof fiber glass cases. Catalog 51-1450. Fischer & Porter Co., Hatboro, Pa.

Handbook of Rockets and Guided Missiles, Norman J. Bowm
Perastadion Press, 10630 S. St. Louis St., Chicago 48, Ill. 328 pp., $6.

U.S. Dept. of Commerce Publications
Order from Office of Technical Services, using the PB number show

(Continued on Page 28)

ENGINEERING DEVELOPMENT

(Continued from Page 21)

An automatic loading mechanism was being develope in a large company without any advice from the analytic section. Structural members which were subjected to co umn buckling loads had been designed with variable cro sections because the design "looked good." Much later th design was reviewed by the analytical section, more o less as a formality. The non-uniform structural sectio required much time for analysis and accurate results we difficult to obtain. As a result it required several weeks o analysis to prove which members were inadequate and t indicate proper revisions. At this stage the revisions re quired much more redesign and in fact the developme work had to be done over again for this phase.

Conclusions

The balance between test and calculation can onl logically be decided on the basis of minimum cost an minimum time. In most instances a thorough cost accoun ing system where each of the two procedures has bee used would shed some interesting light on this subje

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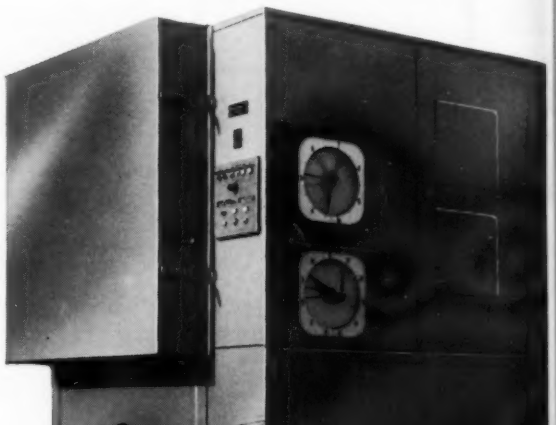

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SHOCK TESTING

(Continued from Page 19)

Since the test samples effect the results so greatly, the results from different machines are difficult to correlate. This has resulted in the empirical method of specifying tests, that is, different heights for different weights of test samples.

The high impact machine is useful in determining the effects of high-acceleration shocks on the performance of the test assembly. High-acceleration shocks can be produced by such things as naval broadsides, near misses with mines, shells, etc. In these cases considerable vibration would be induced as in the test sample.

Spring Type Machines

Several types of shock machines have been devised that make use of coil springs as the decelerating agent. Some of these have been recognized by specifications as standard test machines, for example, JAN-S-44 (Relays).

The simplest design is the table shown in Figure 3. Coil springs are mounted on the under surface. When the table is released by means of a "bomb release" mechanism, the table falls and the springs strike the solid foundation of the machine. The springs are compressed, the stiffness of the spring producing the resisting force and the resulting deceleration. With this method, the following equation gives the acceleration (a) in G units where h is the height of the drop and X is spring compression.

$$a = 2\lambda/X$$

With this type of tester the rise time can be fairly fast followed by a pulse of appreciable duration. To prevent additional accelerations and deceleration, however, some form of a catching device must be used to prevent rebound. Rebound might produce fairly high level short duration shocks that could be undesirable.

Sand Type Machine (Medium Impact)

The unit shown in Figure 4 consists of a flat steel table mounted on a steel structure to which varying numbers of wooden blocks can be attached. The whole assembly is dropped from a pre-determined height. During the fall the potential energy of the raised platform is converted to kinetic energy which in turn is dissipated on striking the sand in the box. This dissipation results in a deceleration of the test sample. By varying the number of blocks under the table the deceleration may be varied. This factor may also be varied by adjusting the height of free-fall. The relatively large platform (3 feet square) enables large test samples to be handled.

With this machine the sand must be loosened and levelled carefully after each test. The loosening may be done either by raking or by the use of bellows. When the loosening is done by means of a rake, a discontinuity occurs in the calibration caused by energy still remaining in the table once the loosened sand has been packed. This residue must be dissipated in the packed lower layers of sand. The point of the discontinuity is a function of the energy to be dissipated, that is, weight of the test sample and the drop height. Unless the bellows used are such that the sand is raised at several points over the area of the sand box, the mass of sand is simply raised and then deposited back in its original position with very little loosening.

The wave form shown in Figure 5 is a typical one although there is considerable variance in the detail shape and deceleration levels. Repeatability is virtually non-existent unless the operator is well-trained and has participated in the calibration. Both the balancing of the table and the levelling of the sand are very critical. An imbalanced table or uneven sand will cause the table to strike so as to produce a double pulse where the pulses

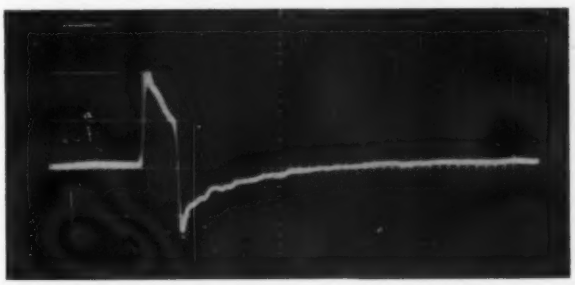

Figure 8. Typical waveform on lead block decelerator.

may reach an extremely high factor.

An examination of the waveform (Fig. 5) will show that this machine produces a relatively slow time of rise. The duration of the pulse is usually in the order of 5 to 8 milliseconds. Considerable ringing is present owing to the deceleration being transferred to the test table at several points over a considerable area. The deceleration tends to vary during the period largely because of variations in sand density and the lack of flow in the sand. This means that the band of frequencies excited is limited on both extremes.

Calibration tests on this machine have shown that decelerations over the range of 15 to 100 G can be produced with durations of from 3 to 8 milliseconds with a repeatability on deceleration of about $\pm$ 20%.

Lead Block Decelerator

The unit shown in Figure 6 is a small drop tester used for the calibration of transducers. In this case the transducer system is taken to include the basic transducer plus cathode followers, filter, and recorder. Although only a small unit is illustrated, similar units have been built capable of coping with loads up to several thousand pounds. The larger unit shown in Figure 7 is one undergoing construction at this time in our Environmental & Appraisal Laboratory.

The units consist basically of a table well ribbed to ensure a high resonant frequency. The spike in the center of the test table strikes the lead and the deceleration is spread to the table by the stiffening webs. The test table is released from a predetermined height and allowed to fall freely to strike the lead. The free falling factor has

a major effect on the waveform by eliminating bearing chatter owing to unbalances and mis-alignments and thus removing unwanted lateral vibrations. The energy dissipated in these unwanted effects would make it impossible to carry out an absolute calibration of the drop tester using a track.

This type of machine capitalizes on a property of commercially pure lead seldom used in other applications. If lead is struck at a relatively high impact velocity, it flows as a liquid. As with liquid, the penetration of the spike into the lead is resisted by the viscosity of the lead. This resistance is used to dissipate the energy present in the falling mass and hence produce a deceleration.

For a cylindrical spike, the resistance produced by the viscosity of the lead acts only on the face of the spike. Because this is true, the deceleration produced by a given spike is constant regardless of the height and can be given as so many pounds of force. As the height is varied, the energy to be dissipated is varied and hence the decelerating force must be present for varying periods of time resulting in different penetrations. Thus both the level of deceleration and the duration of the pulse are controllable. In the case of a cylindrical spike, the deceleration is applied very fast, and the rise time of a typical shock wave such as shown in Figure 8 is in the order of 250 to 500 microseconds. Once the calibration of the system has been completed, conditions, in general, are repeatable to approximately $\pm$ 5%.

Figure 9. Pendulum type lead block decelerator.

This type of shock tester can be calibrated from ba principles, provided that the height of drop is ve much greater than the depth of penetration. With th proviso, the deceleration in G's is the ratio of the heig over penetration. Ideally, if calibration is carried out a manner such that the table bounces to the level of th surface of the lead, then the above proviso does no apply and height/penetration gives the actual G. I

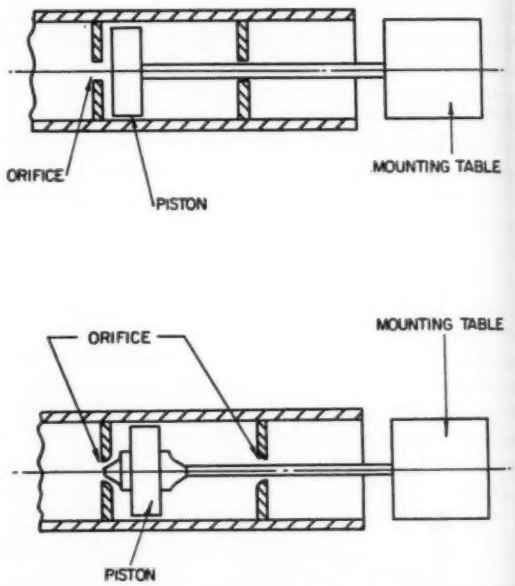

Figure 10. Two forms of hydraulic shock testers.

practice, however, the friction of the lead on the sides o the spikes will prevent this bounce and will also serv to damp out any vibrations present in the spike.

The unit shown in Figure 6 has been used to produc shock waves over the range of 20 G to 200 G on smal test samples.

Once the constants of the lead being used are known the shapes of spikes can be calculated to produce various wavefronts. In this case the decelerating force against th projected area would be used to establish the various diameters required. The longitudinal position of the reference diameters would be governed by the time re quirements of the waveform. The duration of the pulse can be controlled by the height of drop and the mass. In this way shock tests with specific bandwidths can be carried out and used to simulate transient vibration conditions.

The free fall type of lead block decelerator has two major disadvantages in practice:

1. The test sample must be located so that the center of gravity is in line with the point of support and the point of impact, that is, the spike. This is essential

to ensure that the spike strikes the lead normal to the surface.

2. The test sample falls a considerable distance to ensure that enough energy is present to give the correct deceleration when it is dissipated. This means that electrical power and monitoring leads must be long, with the result that noise may be developed and great care must be taken to ensure that leads are not broken.

Drop towers have been built up to heights of 250 feet, and these problems would be very serious during a fall of this nature.

Some lead block machines have been built where the test sample moves only a short distance. One of these is illustrated in Figure 9. In this case the hammer is released from a specific height. It then swings down and strikes the test table via a hard rubber block. The table then accelerates until a spike on the front of the table strikes a lead block and the sample is decelerated. In this case, the test sample is subjected to a double shock –one of deceleration and one of acceleration. The resulting problem is one of deciding which pulse caused the failure.

Other variants have the sample swung as a pendulum and striking a lead block. Others have a lead block swung as a pendulum, striking the test sample and producing an acceleration which is then dissipated at a much lower G in a separate retarding assembly.

In all these variants the advantage of being able to calibrate from basic principles is lost with a resulting dependency on a calibrated measurement system. The losses in the moving parts are considerably greater than those present in a falling device using bearings and guide rails and hence a less efficient machine results. In many cases, however, where a small movement, either linear or angular, is a prime requisite, these difficulties are overcome and such a machine becomes a useful tool.

Hydraulic Machines

Hydraulic shock machines have come into their own as limitations of the lead block decelerator becomes known, particularly with respect to pulses with longer duration than 8 to 10 milliseconds. For long-duration pulses, the height of tower required to build up sufficient energy with lead block decelerators is such that costs become exorbitant. And the higher the drop tower, the more difficult electrical monitoring becomes. The difficulty in handling large objects in a lead block decelerator also indicated a need for a means of producing shock waves with a horizontal movement.

If pulses with a sharp time of rise are required, a piston and orifice arrangement such as is shown in Figure 10 is required. In this case, the hydraulic pressure is built up in the top of the cylinder. This pressure acts on the surface of the piston exposed through the orifice. When this pressure has been built up to the point where it exceeds the force necessary to move the test sample, the piston will move. When this happens the oil pressure will act over the whole area of the piston and a sudden

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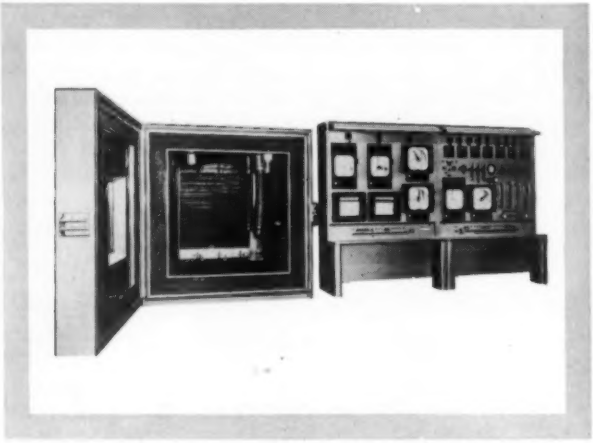

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increase of the force acting on the test sample results. Since this large force is operating on the test sample, a high acceleration results. Because the change from balance to full force is very rapid, a wave front approximating an ideal shock results. The test sample is brought to rest by similar use of an orifice at the limit of travel. With this mode of operation, the sample may be moved several inches with machines having movements up to 24 inches for special applications. By variations in the pressure, different loadings are accommodated. Similarly, variations in pressure will give different accelerations for a given mass.

When a specific waveshape is required, a metering pin is used in the orifice. Where a shaped metering pin is used in lieu of a flat ended piston, the hydraulic pressure acts on the projected area of the pin. As the area of the pin is increased, the acceleration of the test sample is increased. Thus by calculating the shape of the pin, the rise time of the shock wave can be made to conform to a specialized requirement. The following acceleration can similarly be made to conform to the specific wave duration. By use of a similar metering pin, the sample may be brought to rest with a symmetrical waveform.

This machine lends itself to a limited horizontal movement and can be used readily with units where complex electrical monitoring is required. Horizontal movement also lends itself to simpler methods of rigging the test sample.

For large pieces of equipment this type of unit is preferable to the leadblock decelerator. For small items

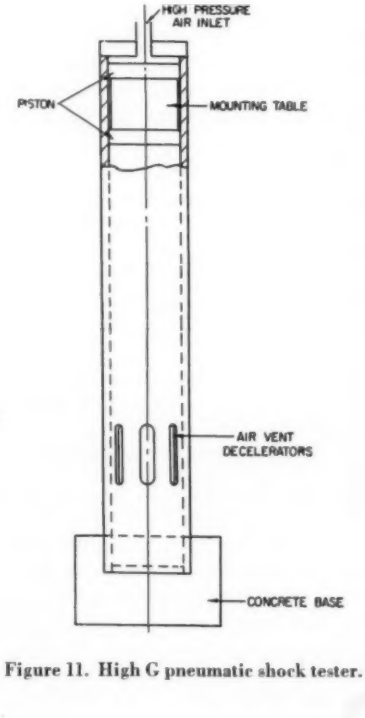
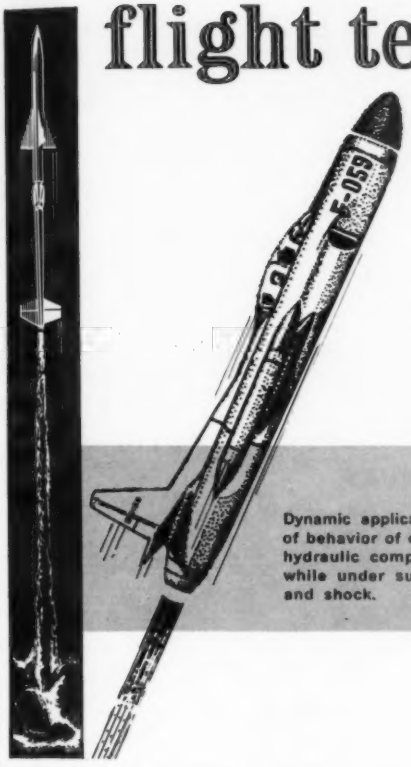


Figure 11. High G pneumatic shock tester.

flight testing on the ground



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such as components, the economics on the use of hydraulics becomes rather debatable. For larger units, high pressure fluid is used and personnel must be thoroughly trained in its handling.

With suitably fitted control valves this same type of machine could readily be adapted to supply high-force, large-displacement, low-frequency vibrations to the test sample. By suitably energizing these valves the oil flow can be modulated to produce the required waveshape.

Pneumatic Machines

Pneumatic machines used in shock testing are fundamentally the same as the hydraulic types. Pneumatic machines, however, came into common use in the production of very high decelerations (10,000 G and higher) long before hydraulic units.

A very common method of producing these very high G decelerations is to have a long air gun with several short slots near its base, as shown in Figure 11. The test sample is mounted on a projectile at the top end of the barrel. The projectile is a tight fitting piston designed so that air pressure built up behind it will cause it to accelerate. The longer this acceleration functions the higher will be the velocity of the projectile.

As the sample moves along the barrel, the air moving in front of it escapes through the slots. As the projectile begins to pass the slots, the flow of air is restricted and a back pressure starts to build up, retarding the projectile slightly. As soon as the slots are covered, the forward movement of the projectile is rapidly halted. This type of unit is a compressed air free fall type of unit where the energizing acceleration is considerably greater than unity. The decelerating force is not constant as with a lead block, however, but increases as the air pressure is increased, and thus a deceleration approximating a sawtooth results. The duration is normally very short and peak accelerations up to 80,000 G have been achieved.

As with hydraulic units, the level of the G factor in the shock wave can be controlled by the pressure of air used to accelerate the projectile in the barrel.

END

$1 MILLION TEST CHAMBER
(Continued from Page 15)

minute pumps. Evacuation capacity can be doubled for altitudes from 30,000 to 60,000 ft. by the addition of a steam exhauster discharging into a barometric condenser. Another steam jet booster provides for altitudes up to 120,000 ft.

The chamber was designed by Moffatt & Nichol, Inc., of Long Beach, Calif., and built by Walco Engineering and Construction Co., Tulsa, Okla.

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NEW LITERATURE

(Continued from Page 22)

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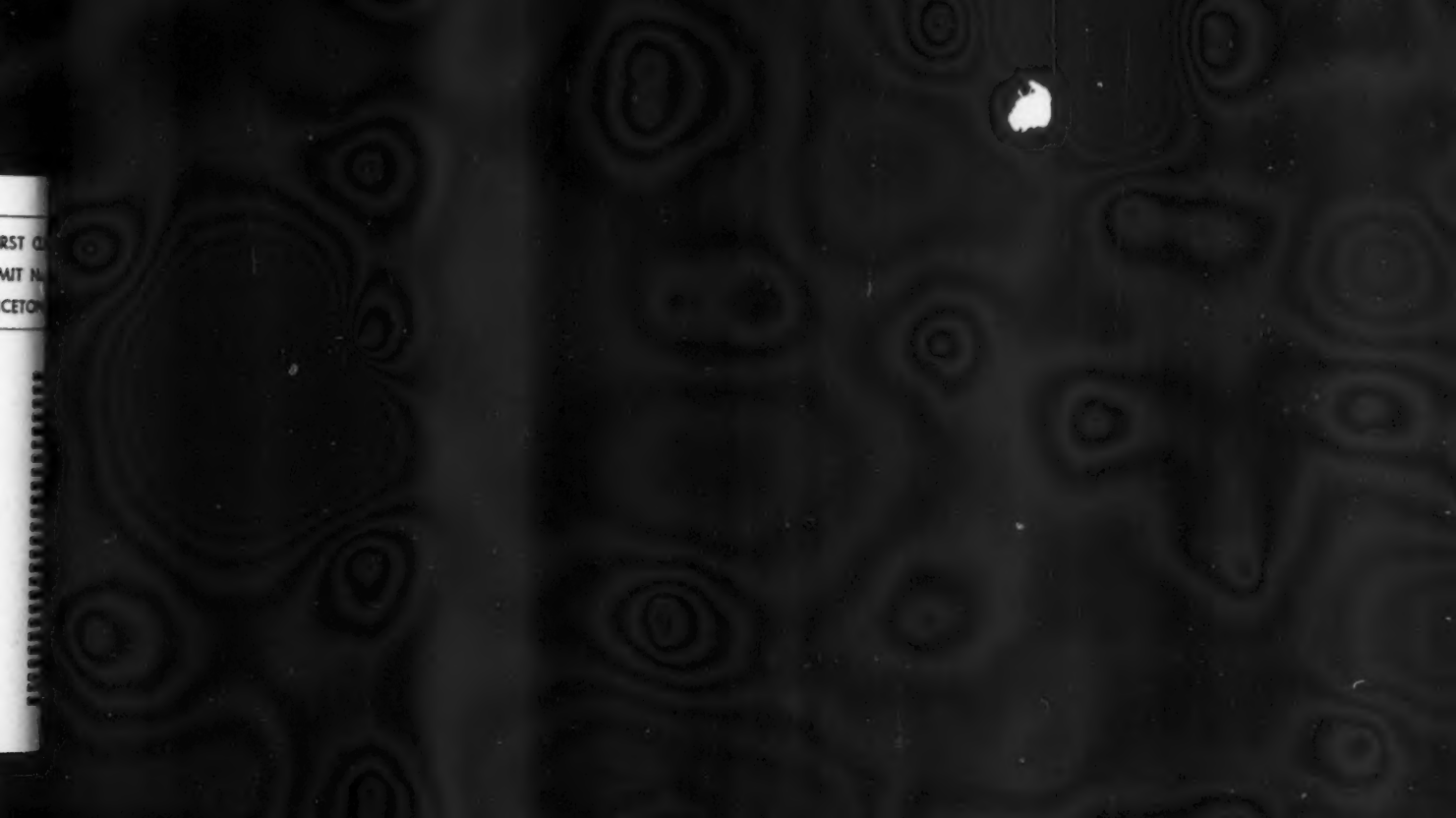

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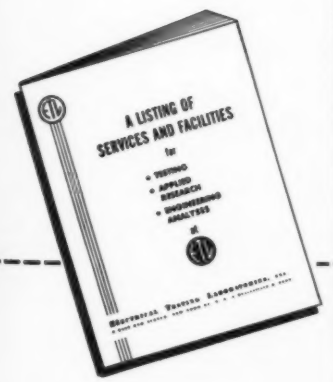

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